INDUSTRIAL DIAMOND

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Diamond is best known for its gem qualities, but some of its unique properties make it ideal for many industrial and research applications as well. Current information on gem-grade diamond can be found in the U.S. Geological Survey (USGS) Minerals Yearbook chapter on gemstones. Diamond that does not meet gem-quality standards for clarity, color, shape, or size is used as industrial-grade diamond. Diamond is the hardest known material and has the highest thermal conductivity of any material at room temperature (May, 1995). Diamond is more than twice as hard as cubic boron nitride or silicon nitride, which are its nearest competitors (Ravi, 1994, p. 537). Because it is the hardest substance known, diamond has been used for centuries as an abrasive in cutting, drilling, grinding, and polishing. Industrial-grade diamond continues to be used as an abrasive for many applications. Even though it has higher unit cost, diamond has proven to be more cost-effective in many industrial processes because it cuts faster and lasts longer than alternative abrasive materials (Boucher, 1997, p. 26.6). Diamond also has chemical, electrical, optical, and thermal characteristics that make it the best material available to industry for wear- and corrosion-resistant coatings, special lenses, heat sinks in electrical circuits, wire drawing, and advanced technologies (like computing).

Both synthetic and natural diamond have industrial uses. Synthetic industrial diamond is superior to its natural diamond counterpart because its properties can be tailored to specific applications, and it can be produced in large quantities (Boucher, 1996). It is for these reasons that manufactured diamond accounts for more than 80% of the industrial diamond used in the United States and the world.

Legislation and Government Programs

Congress has authorized the sale of all diamond in the National Defense Stockpile (NDS), which is managed by the U.S. Department of Defense (DOD). A portion of the stockpiled diamond stones was scheduled for sale in the NDS 2002 annual plan. During 2002, the Defense National Stockpile Center (DNSC) sold 412 thousand carats of diamond stone valued at about $6 million. At yearend 2002, the DNSC reported a NDS remaining inventory of 797 thousand carats of industrial diamond stone (David Warlick, Market Analyst, Defense National Stockpile Center, written commun., 2003). The DOD plans to conduct additional future sales until all NDS diamond stone stocks are sold. Further NDS information is available in the "Prices" section of this report.

Production

The USGS conducts an annual survey of domestic industrial diamond producers and U.S. firms that recover diamond wastes. Although most of these companies responded to the 2002 survey, a few significant firms withheld certain data that they deemed confidential. Thus, only estimates of U.S. primary and secondary output are provided in this review.

As one of the world's leading producers of synthetic industrial diamond, the United States accounted for an estimated output of 219 million carats in 2002. Only two U.S. companies produced synthetic industrial diamond during the year—Mypodiamond, Inc., Smithfield, PA, and GE Superabrasives, Worthington, OH. General Electric Co., Fairfield, CT, which owns GE Superabrasives and other diamond manufacturing plants abroad, is one of the world's largest producers of industrial diamond.

In 2002, nine firms also manufactured polycrystalline diamond (PCD) from synthetic diamond grit and powder. These companies were Dennis Tool Co., Houston, TX; GE Superabrasives, Worthington, OH; Novatek Inc., Provo, UT; Phoenix Crystal Corp., Ann Arbor, MI; Precorp Inc., Provo, UT; SII Megadiamond Industries Inc., Provo, UT; Tempo Technology Corp., Somerset, NJ; U.S. Synthetics Corp., Orem, UT; and Western Diamond Products, Salt Lake City, UT.

It is estimated that more than 5.7 million carats of used industrial diamond was recycled in the United States during 2002. Most of this material was recovered by recycling firms from used diamond drill bits, diamond tools, and other diamond-containing wastes. Additional diamond was recovered during the year from residues generated in the manufacture of PCD; most of this material was recovered from within the production operations of the PCD-producing companies.

The recovery and sale of industrial diamond was the principal business of four U.S. companies in 2002—Industrial Diamond Laboratory Inc., Bronx, NY; Industrial Diamond Powders Co., Pittsburgh, PA; International Diamond Services Inc., Houston, TX; and National Research Co., Fraser, MI. In addition to these companies, other domestic firms may have recovered industrial diamond in smaller secondary operations.

Consumption

The United States remained the world's largest market for industrial diamond in 2002. Based on production estimates, trade data, and adjustments for Government stockpile sales, the apparent U.S. consumption of industrial diamond during the year decreased to an estimated 328 million carats. The major consuming industries of industrial diamond in the United States during 2002 were construction, machinery manufacturing, mining services (drilling), stone cutting/polishing, and transportation systems (infrastructure and vehicles). Within these sectors, stone cutting and highway building/repair together made up the largest demand for industrial diamond. The manufacture of every automobile made in the United States consumes 1.5 carats of industrial diamond. Research and high-technology uses included close-tolerance machining of ceramic parts for the aerospace industry, heat sinks in electronic circuits, lenses for laser radiation equipment, and polishing silicon wafers and disks drives in the computer industry (Bailey and Bex, 1995).

Diamond tools have numerous industrial functions. Diamond drilling bits and reaming shells are used principally for gas, mineral, and oil exploration. Other applications of diamond bits and reaming shells include foundation testing, masonry drilling, and inspecting concrete in various structures. The primary uses of point diamond tools are for dressing and truing grinding wheels and for boring, cutting, finishing, and machining applications. Beveling glass for automobile windows is another application. Cutting dimension stone and cutting/grooving concrete in highway reconditioning are the main uses of diamond saws; other applications include cutting composites and forming refractory shapes for furnace linings. Very fine diamond saws are used to slice brittle metals and crystals into thin wafers for electronic and electrical devices. Diamond wire dies are essential for high-speed drawing of fine wire, especially from hard, high-strength metals and alloys. The primary uses of diamond grinding wheels include edging plate glass, grinding dies, grinding parts for optical instruments, and sharpening and shaping carbide machine tool tips.

Two types of natural diamond are used by industry—diamond stone (generally larger than 60 mesh/250 microns) and diamond bort (smaller, fragmented material). Diamond stone is utilized mainly in drilling bits and reaming shells used by mining companies; it also is incorporated in single- or multiple-point diamond tools, diamond saws, diamond wheels, and diamond wire dies. Diamond bort is used for drilling bits and as a loose grain abrasive for polishing. Other tools that incorporate natural diamond include engraving points, glass cutters, bearings, and surgical instruments.

Synthetic diamond grit and powder are used in diamond grinding wheels, saws, impregnated bits and tools, and as a loose abrasive for polishing. Diamond grinding wheels can be as much as 1 meter in diameter. Loose powders made with synthetic diamond for polishing are used primarily to finish cutting tools, gemstones, jewel bearings, optical surfaces, silicon wafers, and wiredrawing dies for computer chips. Hundreds of other products made from ceramics, glass, metals, and plastics also are finished with diamond powders.

The use of polycrystalline diamond shapes (PDSs) and polycrystalline diamond compacts (PDCs) continues to increase for many of the applications cited above, including some of those that employ natural diamond. The use of PDSs, PDCs, and matrix-set synthetic diamond grit for drilling bits and reaming shells has increased in recent years. PDSs and PDCs are used in the manufacture of single- and multiple-point tools, and PDCs are used in a majority of the diamond wire-drawing dies.

Prices

Natural and synthetic industrial diamonds differ significantly in price (Boucher, 1997, p. 26.6). Natural industrial diamond normally has a more limited range of values. Its price varies from about $0.30 per carat for bort-size material to about $7 to $10 per carat for most stone, with some larger stones selling for up to $200 per carat.

Synthetic industrial diamond has a much larger price range than natural diamond. Prices of synthetic diamond vary according to particle strength, size, shape, crystallinity, and the absence or presence of metal coatings. In general, synthetic diamond prices for grinding and polishing range from as low as $0.40 per carat to $1 per carat. Strong and blocky material for sawing and drilling sells for $1.50 to $3.50 per carat. Large synthetic crystals with excellent structure for specific applications sell for many hundreds of dollars per carat (Law-West, 2002, p. 23.8).

In 2002, the DNSC awarded bids that ranged from $2.91 to $45.51 per carat for NDS diamond stone sold, with the average awarded bid being $14.50 per carat (Mory, 2002).

Foreign Trade

The United States continued to lead the world in industrial diamond trade in 2002; imports were received from 42 countries, exports were sent to 48 countries, and reexports were sent to 38 countries (tables 1-4). Although the United States has been a major producer of synthetic diamond for decades, growing domestic markets have become more reliant on foreign sources of industrial diamond in recent years. U.S. markets for natural industrial diamond always have been dependent on imports and secondary recovery operations because there has been no domestic production of natural diamond.

During 2002, U.S. imports of industrial-quality diamond stones (natural and synthetic) decreased by about 16.5% from 2001 to more than 2.0 million carats valued at more than $12.5 million (table 1). Imports of diamond powder, dust, and grit (natural and synthetic) decreased by 34% from 2001 to 185 million carats valued at about $62 million (table 2).

Reexports can account for a significant portion of total exports/reexports; therefore, exports and reexports are listed separately in tables 3 and 4 so that U.S. trade and consumption can be calculated more accurately. During 2002, U.S. exports of industrial diamond stone increased by approximately 6% from 2001 to 1.14 million carats valued at $8.65 million (table 3). U.S. reexports of industrial diamond stone increased by approximately 3% from 2001 to 1.29 million carats valued at $11.1 million (table 3). U.S. exports of industrial diamond powder, dust, and grit (natural and synthetic) decreased by 7% from 2001 to 81.9 million carats valued at $54.7 million, and reexports of industrial diamond powder, dust, and grit (natural and synthetic) increased by 6% from 2001 to 7.78 million carats valued at $4.17 million (table 4).

World Review

Total 2002 industrial diamond output worldwide during the year was estimated by USGS to be in excess of 800 million carats valued between $600 million and $1 billion. World demand for industrial diamond in the 1990s had been growing at rates of more than 10% per year (Boucher, 1997, p. 26.6).

In 2002, industrial diamond was produced in 32 countries (tables 5, 6). In addition to the countries listed in table 6, Germany and the Republic of Korea produced synthetic diamond, but specific data on their output could not be confirmed. China may have produced more than the output listed in the table (Wilson Born, National Research Co., oral commun., 2002).

In 2002, almost 70% of the total global natural and synthetic industrial diamond output was produced in Australia, Ireland, Russia, South Africa, and the United States. The dominance of synthetic diamond over natural diamond was even more pronounced, as synthetic diamond accounted for more than 80% of global production and consumption.

The Ekati Diamond Mine, Canada's first operating commercial diamond mine, completed its fourth full year of production. In 2002, Ekati produced about 4.98 million carats of diamond (BHP Billiton Ltd., 2003). BHP Billiton has an 80% controlling ownership of the Ekati Mine in the Northwest Territories, Canada. Ekati has estimated reserves of 60.3 million metric tons (Mt) of ore in kimberlite pipes, containing 54.3 million carats of diamond, and the mine life is projected to be 25 years. Operating at full capacity, Ekati production is expected to range from 3.5 million to 4.5 million carats per year (BHP Billiton Ltd., 2001). Ekati diamonds are sold by the BHP Billiton Diamonds Inc. sales office in Antwerp (65%) and by Diamond Trading Company (35%), but since the end of 2002, all Ekati diamonds are sold only by the BHP Billiton Diamonds Inc. Antwerp sales office (Jewelers' Circular Keystone, 2002). Ekati is now producing from the Koala, Panda, and Misery kimberlite pipes (BHP Billiton Ltd., 2001). The mine already accounts for 4% of the world market by weight and 6% by value (Law-West, 2002). In 2002, BHP Billiton began using underground mining techniques to recover diamond from deeper portions of two of the Ekati kimberlite pipes—Koala and Panda—which were first opened pit mined (Diamond Registry Bulletin, 2002). Approximately one-third of the Ekati diamond production is industrial-grade material (Darren Dyck, Senior Project Geologist, BHP Diamonds, Inc., oral commun., May 27, 2001). De Beers' hold on the world diamond market was further reduced at the end of 2002 when the agreement between Ekati and De Beers to sell 35% of Ekati production to De Beers expired and was not renewed. The agreement helped Ekati enter the world diamond market and ended on good terms (Jewelers' Circular Keystone, 2002).

The Diavik Diamond Mine is also in the Northwest Territories. Diavik has estimated reserves of 25.6 Mt of ore in kimberlite pipes, containing 102 million carats of diamonds, and the mine life is projected to be 20 years (Diavik Diamond Mines Inc., 2000, p. 10-12). Diavik received the required permits and regulatory approval in 2000 and began site infrastructure development and project construction. Diavik is an unincorporated joint venture between Diavik Diamond Mines Inc. (60%) and Aber Diamond Mines Ltd. (40%). The Diavik Mine began diamond production in December 2002, and by February 2003, it was expected to reach full production 60 days ahead of the projected opening date (Professional Jeweler, 2002§[1]). The mine is expected to produce about 102 million carats of diamond at a rate of 6 million carats per year worth an average of $63 per carat (Diavik Diamond Mines Inc., 2000, p. 10-12).

A third commercial Canadian diamond project in the Northwest Territories is the Snap Lake diamond project. De Beers Canada Mining Inc. has projected that Snap Lake would begin production in 2006 or 2007 (Law-West, 2002). The Snap Lake diamond project has estimated reserves of 22.8 Mt of ore in a kimberlite dike that contains 38.8 million carats of diamond. The mine life is projected to be 20 years or more (Jack T. Haynes, Assistant Site Manager, De Beers Canada Mining Inc., oral commun., 2001).

Diamond exploration is continuing in Canada, and many new deposits have been found. There are several other commercial diamond projects and additional discoveries in Alberta, British Columbia, the Northwest Territories, Nunavut, Ontario, and Quebec. When the Snap Lake Mine begins production, Canada could account for 15% to 20% of the total world diamond production. If Canadian production continues to increase at about the same rate, Canada will probably eclipse South Africa's diamond production within a decade.

Towards the end of 2001, De Beers quietly settled private civil class actions related to the industrial diamond case in Ohio against De Beers Industrial Diamonds Division (Pty) Ltd. and General Electric Co. The settlement established a $20 million cash fund plus interest and also provided for payment of an in-kind rebate of industrial diamonds that "class members" purchase from the plaintiffs during the period from January 1, 2002, to December 31, 2003. Such a settlement does not legally constitute a formal admission of guilt. The settlement covered alleged illegal price fixing that took place during a period from November 1, 1987, through May 23, 1994. The timing of the settlement should be viewed in the context of the policy of De Beers to conform with local laws of each jurisdiction in which the company conducts business (Tacy Diamond Intelligence, 2002§).

Outlook

The United States will most likely continue to be the world's largest market for industrial diamond well into the next decade. The United States also should remain a significant producer and exporter of industrial diamond. The strength of U.S. demand will depend on the vitality of the Nation's industrial base and on how well the diamond life cycle cost-effectiveness compares with competing materials that initially are less expensive. The many advantages that diamond offers for precision machining and longer tool life, which compensate for increases in other production line costs, seem certain to spur demand for diamond tools. In fact, even the use of

[1]References that include a section mark (§) are found in the Internet References Cited section.

wear-resistant diamond coatings to increase the life of materials that compete with diamond promises to be a rapidly growing application (May, 1995). Increased tool life not only leads to lower costs per unit of output but also means fewer tool changes and longer production runs (Advanced Materials & Processes, 1998). In view of the many advantages that come from increased tool life and reports that diamond film surfaces can increase durability by a factor of 50, much wider use of diamond as an engineering material is expected.

The most dramatic increase in U.S. demand for industrial diamond is likely to be in the construction sector as the Nation builds and repairs the U.S. highway system in its implementation of the Transportation Equity Act for the 21st Century (Public Law 105-178, enacted June 9, 1998). The Act provides funding for the building and repair of the Nation's highway system through 2003. Demand for saw-grade diamond alone is expected to increase by more than $1 billion during the coming year if goals mandated by the Act for the repair and replacement of roads, bridges, and other components in the transportation infrastructure of the country are fulfilled (Wilson Born, National Research Co., oral commun., 2001). The Safe, Accountable, Flexible, and Efficient Transportation Equity Act of 2003 (S. 1072, H.R. 2088), which is expected to be enacted in early 2004, will continue this funding for the building and repair of the Nation's highway system (U.S. Senate, 2003§).

One U.S. company, Apollo Diamond, Inc., developed and patented a method for growing gem-quality diamond by chemical vapor deposition (CVD). The CVD technique transforms carbon into plasma, which then is precipitated onto a substrate as diamond. CVD has been used for more that a decade to cover large surfaces with microscopic diamond crystals, but until now, no one had discovered the combination of temperature, gas composition, and pressure that results in the growth of a single diamond crystal. CVD diamond can be grown for about $5 per carat. The promise of CVD is that it produces extremely pure crystal. CVD diamond precipitates as nearly 100%-pure diamond and therefore may not be discernible from natural diamond. But the greatest potential for CVD diamond is in computer technology. For diamond to be a practical material for use as a semiconductor, it must be affordably grown in large wafers. CVD growth is limited only by the size of the seed placed in the Apollo machine. Starting with a square, wafer-like fragment, the Apollo Diamond process will grow the diamond into a prismatic shape, with the top slightly wider than the base. For the past 7 years, Apollo Diamond has been growing increasingly larger seeds by chopping off the top layer of growth and using that as the starting point for the next batch. At the moment, the company is producing 10-millimeter wafers but predicts it will reach about 10 times that in 5 years (Davis, 2003). Scientists have said that diamond computer chips are more durable because they can work at a temperature of up to 1,000° C, while silicon computer chips stop working at about 150° C. This means that diamond computer chips can work at a much higher frequency or faster speed and can be placed in a high-temperature environment (Diamond Registry Bulletin, 2003§).

According to industry sources, PCD for abrasive tools and wear parts will continue to replace competing materials in many industrial applications by providing closer tolerances as well as extending tool life. For example, PDCs and PDSs will continue to displace natural diamond stone and tungsten carbide products used in the drilling and tooling industries (Wilson Born, National Research Co., written commun., 1998).

Truing and dressing applications will remain a major domestic end use for natural industrial diamond stone. Stones for these applications have not yet been manufactured economically. No shortage of the stone is anticipated, however, because new mines and more producers selling in the rough diamond market will maintain ample supplies. More competition introduced by the additional sources also may temper price increases.

World demand for industrial diamond will continue to increase during the next few years. Constant-dollar prices of synthetic diamond products, including chemical-vapor-deposition diamond films, will decline as production technologies become more cost effective and as competition increases from low-cost producers in China and Russia.

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TABLE 1
U.S. IMPORTS FOR CONSUMPTION OF INDUSTRIAL DIAMOND STONES, BY COUNTRY[1]

(Thousand carats and thousand dollars)

	Natural industrial diamond stones[2]				Miners' diamond, natural and synthetic[3]			
	2001		2002		2001		2002	
Country	Quantity	Value[4]	Quantity	Value[4]	Quantity	Value[4]	Quantity	Value[4]
Australia	6	72	4	29	1	22	1	33
Belgium	53	345	103	372	41	526	65	453
Botswana	(5)	186	(5)	12	--	--	80	471
China	22	76	4	7	--	--	--	--
France	--	--	(5)	3	80	99	(5)	5
Ghana	1	15	75	177	(5)	26	163	450
Guyana	3	18	--	--	22	1,250	56	3,170
India	3	18	131	29	(5)	4	4	40
Ireland	322	871	205	2,910	36	81	259	253
Namibia	28	142	41	148	3	18	--	--
Netherlands	--	--	5	21	53	916	33	645
Russia	261	290	7	78	587	485	170	387
Switzerland	17	100	2	68	787	1,100	383	429
United Kingdom	43	196	47	140	46	1,190	103	152
Other	36 r	332 r	69	645	7	307 r	38	1,410
Total	794	2,660	692	4,640	1,660	6,030	1,360	7,900

[r]Revised. -- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes glazers' and engravers' diamond unset, Harmonized Tariff Schedule of the United States (HTS) codes 7102.21.3000 and 7102.21.4000.
[3]HTS codes 7102.21.1010 and 7102.21.1020.
[4]Customs value.
[5]Less than 1/2 unit.

Source: U.S. Census Bureau.

TABLE 2

U.S. IMPORTS FOR CONSUMPTION OF DIAMOND POWDER, DUST AND GRIT, BY COUNTRY[1]

(Thousand carats and thousand dollars)

	Synthetic[2]				Natural[2]			
	2001		2002		2001		2002	
Country	Quantity	Value[3]	Quantity	Value[3]	Quantity	Value[3]	Quantity	Value[3]
Belgium	1,750	666	3,210	1,010	6,090	3,580	5,030	2,970
China	55,100	6,250	39,800	5,620	8,330	521	2,030	208
Czech Republic	335	84	8,170	1,590	--	--	363	204
Germany	1,660	2,000	144	42	--	--	2	3
India	2,660	588	572	177	2,080	906	195	60
Ireland	98,100	44,100	63,500	31,700	2,030	1,220	2,090	1,060
Italy	3,250	1,330	1,630	730	57	25	50	13
Japan	6,860	2,880	4,530	3,460	195	320	312	347
Korea, Republic of	12,800	5,700	9,360	5,000	2	4	18	8
Macau	426	72	742	130	--	--	--	--
Romania	608	123	407	89	--	--	5	21
Russia	16,400	2,520	10,800	1,370	2,240	484	2,310	515
Switzerland	6,050	3,640	871	493	460	699	2,380	1,120
Ukraine	47,500	4,460	22,100	1,770	--	--	--	--
United Kingdom	3,190	1,140	2,940	857	705	268	820	334
Other	1,920 r	1,360 r	738	697	301	389 r	499	321
Total	259,000	76,900	169,000	54,700	22,500	8,420	16,100	7,180

[r]Revised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Harmonized Tariff Schedule of the United States codes: synthetic, 7105.10.0020, 7105.10.0030, and 7105.10.0050; natural, 7105.10.0011 and 7105.10.0015.

[3]Customs value.

Source: U.S. Census Bureau.

TABLE 3
U.S. EXPORTS AND REEXPORTS OF INDUSTRIAL DIAMOND STONES, BY COUNTRY[1]

(Thousand carats and thousand dollars)

	Industrial unworked diamonds[2]			
	2001		2002	
Country	Quantity	Value[3]	Quantity	Value[3]
Exports:				
Australia	5	51	2	27
Belgium	167	1,590	15	146
Bulgaria	37	48	38	56
Canada	113	411	103	341
Germany	35	249	15	114
Hong Kong	83	825	233	2,050
Israel	13	133	--	--
Japan	360	3,600	294	2,540
Korea, Republic of	69	705	96	990
Malaysia	44	428	31	124
Mexico	15	148	84	418
Poland	14	140	2	18
Thailand	25	248	58	585
Other	99 r	961 r	169	1,240
Total	1,080	9,530	1,140	8,650
Reexports:				
Belgium	790	7,250	611	6,220
Canada	90	308	191	584
Germany	52	386	53	460
Hong Kong	(4)	3	7	75
Ireland	36	237	24	162
Israel	83	971	34	262
Japan	80	833	111	1,110
Korea, Republic of	57	622	47	481
Mexico	4	63	4	35
Netherlands	13	131	44	438
Switzerland	19	112	(4)	5
United Arab Emirates	--	--	80	454
United Kingdom	20	225	64	608
Other	10 r	83 r	22	217
Total	1,260	11,200	1,290	11,100
Grand total	2,330	20,800	2,430	19,800

[r]Revised. -- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Harmonized Tariff Schedule of the United States code 7102.21.0000.
[3]Customs value.
[4]Less than 1/2 unit.

Source: U.S. Census Bureau.

TABLE 4

U.S. EXPORTS AND REEXPORTS OF INDUSTRIAL DIAMOND POWDER, DUST AND GRIT, BY COUNTRY[1]

(Thousand carats and thousand dollars)

	Synthetic[2]				Natural[2]			
	2001		2002		2001		2002	
Country	Quantity	Value[3]	Quantity	Value[3]	Quantity	Value[3]	Quantity	Value[3]
Exports:								
Austria	2,760	2,200	1,170	685	59	61	53	9
Belgium	1,510	669	757	473	275	399	118	282
Brazil	1,370	651	2,350	863	13	15	38	12
Canada	1,590	2,180	2,390	2,100	263	227	166	121
France	338	115	68	42	73	175	41	42
Germany	3,280	2,070	1,020	526	263	698	640	844
Greece	132	141	317	180	--	--	--	--
Hong Kong	300	339	537	658	227	195	314	255
India	1,320	661	1,680	715	7	16	64	79
Ireland	26,000	19,300	27,600	20,400	153	144	20	37
Israel	364	204	374	183	150	40	45	27
Italy	1,920	934	1,150	481	44	25	248	104
Japan	17,400	10,200	14,700	9,530	1,010	2,140	738	1,480
Korea, Republic of	12,400	5,520	12,100	5,300	424	178	397	131
Macau	162	29	746	167	--	--	--	--
Malaysia	529	501	243	273	13	9	27	28
Mexico	208	149	407	210	170	102	73	56
Netherlands	329	350	159	222	1,830	2,710	387	600
Philippines	225	317	45	56	33	4	--	--
Singapore	84	50	94	113	15	37	11	8
Spain	336	99	252	92	24	10	113	47
Switzerland	1,260	872	631	489	4,740	5,940	4,150	3,980
Taiwan	1,590	1,050	2,210	1,310	76	145	1,060	144
Thailand	373	356	678	367	3	7	64	54
United Kingdom	665	550	138	61	526	269	159	152
Other	619 r	554 r	572	481	240 r	163 r	524	219
Total	77,100	50,100	72,400	46,000	10,600	13,700	9,450	8,700
Reexports:								
Australia	60	11	34	10	--	--	--	--
Austria	489	100	492	158	123	28	73	57
Belgium	135	61	199	53	40	18	--	--
Brazil	120	25	8	10	--	--	8	5
Canada	640	638	1,120	993	90	69	19	25
France	203	64	26	4	266	42	33	9
Germany	421	208	619	292	55	66	117	91
Hong Kong	--	--	38	49	40	60	20	20
India	11	3	30	17	132	158	22	38
Ireland	18	32	244	174	26	38	2	3
Israel	--	--	--	--	33	6	35	11
Italy	956	397	771	282	66	51	11	5
Japan	113	48	32	21	60	42	20	38
Korea, Republic of	1,430	465	1,770	646	245	114	345	230
Macau	62	77	413	83	--	--	--	--
Malaysia	9	3	87	25	46	11	20	4
Mexico	20	6	(4)	3	11	7	7	13
South Africa	39	7	18	3	--	--	2	6
Spain	22	6	55	24	31	32	13	15
Switzerland	404	153	123	67	132	45	--	--
Taiwan	141	116	229	215	93	69	24	40
United Kingdom	237	84	397	183	179	117	59	76
Other	95 r	94 r	226	156	62 r	29 r	24	16
Total	5,620	2,600	6,930	3,470	1,730	1,000	854	701
Grand total	82,700	52,700	79,400	49,500	12,400	14,700	10,300	9,410

[r]Revised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Harmonized Tariff Schedule of the United States codes: synthetic, 7105.10.0025; natural, 7105.10.0010.

[3]Customs value.

Source: U.S. Census Bureau.

TABLE 5
NATURAL DIAMOND: ESTIMATED WORLD PRODUCTION, BY TYPE AND COUNTRY[1, 2, 3]

(Thousand carats)

Type and country[4]	1998	1999	2000	2001	2002
Gemstones:					
Angola	2,400	3,360	3,914 [5]	4,653 [5]	5,400
Australia	18,400	13,400 [r]	12,000 [r]	10,700	15,100
Botswana	14,800 [r]	17,200 [r]	18,500 [r]	19,800 [r]	21,300
Brazil	100 [5]	900 [5]	1,000 [5]	1,000 [5]	700
Canada	203 [5]	2,429 [5]	2,435 [r, 5]	3,685 [r, 5]	4,984 [5]
Central African Republic	330	311	346	360	375
China	230	230	230	235	235
Congo (Kinshasa)	5,080	4,120	3,500	9,100	9,100
Cote d' Ivoire	210	270	210	210	160
Ghana	658 [r]	546 [r]	792 [r]	936 [r]	770
Guinea	294	287 [r]	278	270	270
Guyana	50 [r, 5]	45 [r, 5]	82 [r, 5]	179 [r, 5]	100
Liberia	150	120	100	100	120
Namibia	1,350 [r]	1,630 [r]	1,450 [r]	1,487 [r, 5]	1,350
Russia	11,500	11,500	11,600	11,600	11,500
Sierra Leone	200	450	450	450	450
South Africa	4,280 [r]	4,010 [r]	4,320 [r]	4,470	4,350
Tanzania	83	200	301	216 [r]	182
Venezuela	80	59	29 [r]	14 [r]	15
Zimbabwe	10	15	8 [r]	-- [r]	--
Other	19 [r]	20 [r]	24 [r]	25 [r]	25
Total, gemstones	60,400	61,100 [r]	61,600 [r]	69,500 [r]	76,500
Industrial:					
Angola	364	373	435	517	600
Australia	22,500	16,381 [5]	14,700	13,100	18,500
Botswana	5,000	5,730 [r]	6,160 [r]	6,600 [r]	7,100
Central African Republic	200	120	115	120	125
China	900	920	920	950	955
Congo (Kinshasa)	21,000	16,000	14,200	9,100	9,100
Cote d' Ivoire	100	128	110	110	90
Ghana	165 [r]	136 [r]	198 [r]	234 [r]	193
Guinea	98	96 [r]	91	100 [r]	100
Liberia	150	80	70	70	80
Namibia	71 [r]	-- [r]	106 [r]	--	--
Russia	11,600	11,500	11,600	11,600	11,500
Sierra Leone	50	150	150	150	150
South Africa	6,420 [r]	6,010 [r]	6,470 [r]	6,700	6,530
Tanzania	15	35	53 [r]	38 [r]	33
Venezuela	17	36	80 [r]	38 [r]	40
Zimbabwe	19	30	15 [r]	-- [r]	--
Other	44 [r]	52 [r]	64 [r]	66 [r]	68
Total, industrial	68,700	57,800 [r]	55,500 [r]	49,500 [r]	55,200
Grand total	129,000	119,000 [r]	117,000 [r]	119,000 [r]	132,000

[r]Revised. -- Zero.
[1]World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.
[2]Table includes data available through May 27, 2003.
[3]In addition to the countries listed, natural diamond is produced in Nigeria, but information is inadequate to estimate output.
[4]Includes near-gem and cheap-gem qualities.
[5]Reported figure.

TABLE 6
SYNTHETIC DIAMOND: ESTIMATED WORLD PRODUCTION, BY COUNTRY[1, 2, 3]

(Thousand carats)

Country	1998	1999	2000	2001	2002
Belarus	25,000	25,000	25,000	25,000	25,000
China	16,500	16,500	16,800	17,000	17,000
Czech Republic	5,000	3,000	--	--	--
France	3,000	3,000	3,000	3,000	3,000
Greece	750	750	750	--	--
Ireland	60,000	60,000	60,000	60,000	60,000
Japan	32,000	32,000	33,000	33,000	34,000
Poland	210	200	--	--	--
Romania	3,000	3,000	--	--	--
Russia	80,000	80,000	80,000	80,000	80,000
Slovakia	5,000	3,000	--	--	--
South Africa	60,000	--	--	60,000	60,000
Sweden	25,000	25,000	20,000	20,000	20,000
Ukraine	8,000	8,000	8,000	8,000	8,000
United States	140,000	161,000 r	182,000 r	202,000 r	222,000
Total	463,000	420,000 r	429,000 r	508,000 r	529,000

[r]Revised. -- Zero.
[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.
[2]Table includes data available through May 27, 2003.
[3]In addition to the countries listed, Germany and the Republic of Korea also produce significant amounts of synthetic diamond, but output is not officially reported, and available information is inadequate to formulate reliable estimates of output levels.